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Technical efficiency of cooperative member vis-à-vis non-member dairy farms in Gujarat – application of data envelopment analysis

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Abstract

Objectives: To compare the technical efficiency scores of dairy cooperative member and non-member farms across the districts in Gujarat selected from regions having different level of dairy development.
Methods/Statistical analysis: The present study has analyzed and compared the technical efficiency of 180 dairy farmers using a non-parametric approach *i.e.,* Data Envelopment Analysis (DEA). The study is based on the primary data collected during 2016-17 using a well-structured, comprehensive and pre-tested interview schedule. Apart from conventional analysis, box-plot and scatter-plot were used to compare the efficiency scores.
Findings: The investigation identified regional disparities in efficiency scores based on dairy development. The DEA results showed that member farmers of the district selected from low (Tapi), moderate (Bharuch) and highly (Anand) dairy developed regions were more efficient than their respective non-member counterpart. Similarly, the overall comparison between dairy cooperative members and non-members showed that the efficiency of member farmers was 83.27% while for non-members it was 75.31%. Further, the results revealed that small herd size farmers were most efficient in both member (87.21%) and non-member (81.59%) categories. The paper established that membership in dairy cooperatives; herd size as well as status of dairy development in a region greatly influences the technical efficiency of farmers.
Application/Improvements: Overall, the study concludes that 24.69% and 16.73% inefficiency exist respectively in dairy cooperatives non-member and member farms indicating the scope for increasing the realized output with same level of resources and production technology.
***Keywords*:** Gujarat, technical efficiency, dairy cooperatives, member, non-member, data envelopment analysis.

1. Introduction

Dairying has become an integral part of Indian rural economy and its prosperity as it generates a regular income flow to the farmers. Dairying in rural areas supplements other seasonal farm activities due to consistent market demand for milk with only marginal seasonal variation in production. India, 'The Oyster' of the global dairy industry contributes the maximum to the world milk production as well as to consumption but the country's milk productivity is far below the world average. Increase in milk production over years is mainly due to increase in herd population as a result of various improved breeding programmes. Productivity growth is much more essential for the sustenance of Indian dairy sector and it can be achieved by improving the technical efficiency of the farmers in milk production [1]. Technical efficiency improvement with the adoption of existing technologies and practices saves the irrational use of scarce resources. In developing countries like India, efficiency analysis in milk production becomes utmost important, where underdeveloped production environments exist which are characterized essentially by low-input and low-output condition with subsistence holding, poor resource capacity, milch animals having low production potential and poor infrastructure support [2].Gujarat is one of the highly dairy progressive states of India [3] and has a vibrant and efficient organized dairy cooperative structure. Dairy cooperatives provide several technical inputs and services to the member farmers which have an effect on their technical efficiency. Technical efficiency is essentially a partial measure of economic efficiency and concentrates on differences in average production between farms in the benchmark

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group [4-6]. Improvement in efficiency requires farmers to adopt modern technologies and practice judicious use of inputs resulting in cost reduction and increased profitability. The least efficient farms fall at the lowest point in regard to adoption of the improved technologies and innovations. The farms with low-level technological adoption accompanied with poor management ability, ultimately result in lower technical efficiency. The wide variation in technical efficiency among farmers, especially between dairy cooperative members and non-members should be thoroughly investigated in order to identify the scope for improvement. In the context, the present study has been carried out in Gujarat to analyze the level of technical efficiency in dairy cooperative member and non-member farms to suggest strategies for enhancing the productivity.

2. Material and methods

Principal component analysis based dairy development index (DDI) [7] was developed for all the districts of Gujarat state. The DDI was constructed by considering various aspects of dairying for the triennium ending 2013-14 data like resource availability, infrastructure and veterinary facilities, and milking animals and their yields. The districts were categorized into high, medium and low based on the DDI. For analyzing technical efficiency, primary data were collected during 2016-17 from randomly selected three districts each belonging to the different level of dairy development. A total sample of 180 dairy farmers was selected from three districts namely; Anand from high, Bharuch from medium and Tapi from low dairy development categories. From each district, 30 co-operative member and 30 non-member dairy farmers were selected randomly. A well-structured, comprehensive and pre-tested interview schedule was used for data collection from the respondents.

1. Technical efficiency estimation using data envelopment analysis (DEA)

Technical efficiency is the ability of a farm/farmer to produce maximum amount of output with the existing level of technology and inputs or resources. Efficiency indicators can be of two forms, either input-oriented or output-oriented. Output-oriented efficiency indicator measures the proportion of output that can be increased without increasing the level of inputs, while the input-oriented efficiency indicator measures the proportion of input use that can be reduced without affecting the level of output. The relative magnitude of the efficiency scores remains same irrespective of whether it is input-oriented or output-oriented.

Two common methodologies have been used for measuring the technical efficiency-econometric (parametric) and mathematical (non-parametric) approach. Both the techniques use different methods to envelop the data, and in doing so they make different accommodation for random noise as well as with respect to flexibility of production technology. Therefore, they differ in many ways. For the present study, non-parametric approach i.e., data envelopment analysis (DEA) has been used owing to its multiple advantages: does not require a parametric specification of the functional form for the frontier, unnecessary structure is not imposed on technology and thereby, prevent distortion in efficiency measures.DEA is a linear programming-based technique in which the production frontier is formed using the sample observations wherein, the best performing farms lie on the frontier and inefficient farms lie below the frontier. The model specification has the assumption that each Decision-Making Unit *i.e* DMU_j (dairy farm in the present study) has multiple inputs, $X_{ij}$and multiple outputs, Y_{kj}. A relative efficiency can be measured by:

$$Efficiency(E_j) = \frac{\sum_k V_k Y_{kj}}{\sum_i W_i X_{ij}}$$

Where, V and W are output and input weights, respectively. The weights are the critical elements in determining the relative efficiencies for each DMU. Each DMU_{jo} is free to set its own weights to solve the optimization problem of maximizing its efficiency subject to the constraints that all efficiencies of other DMUs should be less than or equal to 1 and the weights should be greater than or equal to 0. In mathematical notation, it can be expressed as follows [8]:

$$MaximiseE_j = \frac{\sum_k V_k Y_{kjo}}{\sum_i W_i X_{ijo}}$$

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$$st\frac{\sum_k V_k Y_{kj}}{\sum_i W_i X_{ij}} \leq 1$$
$$V_k W_i \geq 0$$

DEA was initially developed by Charnes, Cooper and Rhodes (1978) from pioneering work of Farrell (1957) and proposed a model (CCR: Charnes, Cooper and Rhodes model) which is input-oriented with assumption of constant returns to scale. For the present study, the dairy farm's technical efficiency was measured by the data envelopment analysis programmed (DEAP) developed by following the steps outlined by [9]. The input-oriented DEA model [10] is specified as:

$$MaximiseE_j = \frac{\sum_k V_k Y_{kjo}}{\sum_i W_i X_{ijo}}$$
$$st\sum_i W_i X_{ijo} = K$$
$$\sum_k V_k Y_{kj} - \sum_i W_i X_{ij} \leq 0$$
$$V_k W_i \geq 0$$

It considers the input component, $W_i X_{ijo}$ as constant K. If E_j=1, it implies that the farm is percent efficient and if it is less than 1, say 0.75, it indicates that the farm is inefficient by 25 percent. The magnitude of inefficiency implies that the output can be increased by the same per cent level with the existing use of resources.

3. Results and discussion

1. Inputs used and output produced in dairy farms

Technical efficiency depends on the extent of resources used in the production process. In the present study, all the inputs were considered in quantity terms barring expenses on veterinary and miscellaneous items. Miscellaneous cost involves the cost of electricity, fuel, stationary charges and cost on items like ropes, bucket, broom, baskets etc. Table 1 shows the mean value of various inputs used and output obtained per animal per day. No significant difference has been observed in the quantity of feed and fodder provided to an animal by the member and non-member dairy farmers.

However, the veterinary and miscellaneous cost was higher for non-member farmers compared to member farmers which could be attributed to the provision of artificial insemination and other medical services by the cooperatives to the member farmers at lower prices than market rate coupled with the nearness of milk collection centers. Similarly, water given to animals and time given for their care was higher for non-members than member farmers. Milk output obtained by the member farmers (5.52 lit/animal/day) was higher than non-members (4.5 liter/animal/day) indicating that the member farmers were able to produce more output with less or same amount of inputs compared to non-members.

Table 1. Summary statistics of inputs used and output produced in dairy farms

Particulars	Member	Non-member
Milk output (liters/animal/day/)	5.52	4.5
Inputs		
Green fodder (kg/animal/day)	13.76	12.73
Dry fodder (kg/animal/day)	10.56	10.05
Concentrates (kg/animal/day)	3.44	3.23
Drinking water(liters/animal/day)	28.52	29.26
Labour man days (hours/animal/day)	3.09	4.47
Veterinary cost (animal/day)	0.96	1.51
Miscellaneous cost (animal/day)	3.72	4.48

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2. Herd size

The households were stratified into three groups based on standard animal units (SAUs) by using cumulative square root frequency method [11]. Three herd size categories viz. small (1-3 SAUs), medium (4-7 SAUs) and large (above 7 SAUs) were obtained using [12] approach for the western region of India.

Table 2. Distribution of farms across herd size categories and districts

Herd size categories	Districts						
	Anand		Bharuch		Tapi		Total
	Member	Non-member	Member	Non-member	Member	Non member	
Small(1-3 SAUs)	9(30.00)	15(50.00)	9(30.00)	16(53.33)	4(13.33)	8(26.66)	61(33.88)
Medium (4-7 SAUs)	12(40.00)	13(43.33)	15(50.00)	13(43.33)	16(53.33)	13(43.33)	8245.56)
Large(>7 SAUs)	9 (30.00)	2 (6.66)	6 (20.00)	1 (3.33)	10 (33.33)	9 (30.00)	37 (20.56)
Total	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	180 (100)

Note: Figures within parentheses indicate percentage to column total

Table 2 shows the distribution of the sample households selected for the study from three different districts. The sample comprised 61 farmers with small herd size, 82 farmers with medium head size and 37 with large herd size. Out of 61 small herd size farms, 39 farms were non-member farms while out of 37 large herd size farms 25 were member farms. The proportion of small, medium and large herd size categories in the sample dairy farms were 33.88, 45.56 and 20.56 percent, respectively. Across districts, medium herd size farms were almost equally distributed among all selected districts and large herd size farms were high (51.36%) in Tapi district, followed by Anand (29.72%) and Bharuch (18.92%). In all the three districts, medium herd size farms were found to be high.

3. Technical efficiency of cooperative member and non-member dairy farms

DEA approach can be employed for multiple output conditions, but in the present study, only milk has been considered as a sole output. DEA has been carried out in two phases for comparison. First, a comparison of the technical efficiency of the member and non-member dairy cooperatives within the individual district has been made. Second, an overall comparison of the technical efficiency of the member and non-member dairy farmers of all districts (pooled sample) was done. It was hypothesized that members of dairy cooperatives were more efficient since the member farmers have access to resources and information which determines their farm management ability. A comparison of efficiency scores was made between the member and non-member farmers across districts having a different level of development (Table 3). The results showed that the member farmers of Anand (91.20%), Bharuch (90.58%) and Tapi (87.09%) were more efficient than their respective counterparts and Anand non-member (75.91%) farmers were least efficient. The divergence in technical efficiencies of the member and non-member dairy cooperative farms was highest in Anand (15.29%), followed by Tapi (6.53%) and Bharuch (5.28%). The divergence was found to be high in the case of Anand because50 percent of the non-member farmers from the highly developed district (Anand) belong to small farmers' category rearing generally only one or two animals to fulfill their need for milk and milk-based products. Further, they mostly rear buffaloes due to the preference of buffalo milk over cow for their consumption. Cooperatives also prescribe a minimum quantity of milk is procured from farmers in order to avail the membership. As these farmers have a less marketable surplus, the left-over milk after consumption has been sent to the consumers directly without selling to cooperatives. Table 4 compares the pooled sample technical efficiency of the cooperative member and non-member dairy farms. The results revealed that the member (83.27%) farmers of Gujarat were more efficient than non-members (75.31%) corroborating the findings of [13], wherein member farmers (79%) were more efficient than non-member farmers (66%) in Northern India. The overall mean efficiency score (79.30%) obtained by the DEA tool indicated that around 21 percent of overuse in inputs can be reduced with the given technology to produce the same level of output and vice-versa. The minimum efficiency score was also lowest for non-members (44.10%), followed by member farmers (45.80%).

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Table 3. Comparison of member and non-member efficiency score across districts

Technical efficiency (%)	Parameter	Anand		Bharuch		Tapi	
		Member	Non-member	Member	Non-member	Member	Non-member
Up to 49.99	Minimum	-	-	-	48.20	-	-
	Mean	-	-	-	48.90	-	-
	Maximum	-	-	-	49.60	-	-
50.00 - 59.99	Minimum	-	50.00	-	55.60	52.70	55.30
	Mean	-	55.88	-	57.75	53.45	56.93
	Maximum	-	59.60	-	59.90	54.20	57.80
60.00 - 69.99	Minimum	66.00	63.80	60.90	64.20	64.80	62.50
	Mean	66.00	67.04	66.08	66.78	66.60	66.07
	Maximum	66.00	69.40	69.30	68.00	67.80	69.20
70.00 - 79.99	Minimum	71.20	70.00	74.00	75.70	70.70	72.00
	Mean	74.34	73.71	76.00	75.80	73.17	76.47
	Maximum	78.60	79.20	76.80	75.90	76.20	79.60
80.00 - 89.99	Minimum	82.20	80.00	83.90	80.00	82.80	80.60
	Mean	85.57	80.00	86.55	82.85	86.70	83.80
	Maximum	88.50	80.00	89.20	85.70	89.40	88.80
90.00 – 100	Minimum	90.10	99.10	90.70	95.40	93.50	93.70
	Mean	97.22	99.90	98.81	99.68	99.16	98.97
	Maximum	100.00	100.00	100.00	100.00	100.00	100.00
Mean efficiency score		91.20	75.91	90.58	85.30	87.09	80.56

The result of analysis on the potential loss of output due to inefficiency showed that cooperative member farmers in Anand on an average can produce 2.3 liters more than their current output while the same was 5.15 liters per farm for non-member farms. In the case of Bharuch and Tapi, the average gap between potential and actual output was 4 liters and 4.52 liters for member farmers, respectively while the corresponding output was 3.31 liters and 5.39 liters for non-member farmers.

Table 4. Technical efficiency across range for members and non-members

Technical efficiency (%)	Parameter	Pooled sample (n=180)	
		Member	Non-member
Upto 49.99	Minimum	45.80	44.10
	Mean	46.83	44.84
	Maximum	48.00	45.40
50.00 - 59.99	Minimum	51.80	50.00
	Mean	55.23	54.90
	Maximum	57.00	58.90
60.00 - 69.99	Minimum	60.20	60.00
	Mean	64.94	65.02
	Maximum	68.10	69.60
70.00 - 79.99	Minimum	70.70	71.00
	Mean	91.80	73.76
	Maximum	79.90	78.00
80.00 - 89.99	Minimum	82.20	80.00
	Mean	86.22	82.80
	Maximum	89.30	86.20
90.00 – 100	Minimum	90.00	91.30
	Mean	97.80	98.97
	Maximum	100.00	100.00
Mean efficiency score		83.27	75.31

A graphical comparison has been made across dairy farms located in different dairy development environment through box-plot analysis (Figure 1,2). The dot in the box plot shows the mean score of technical efficiency, horizontal line at the middle of the box-plot indicates the median and the vertical length of the box-plot reveals the standard deviation. Figure 1 shows the distribution of technical efficiency scores with respect to

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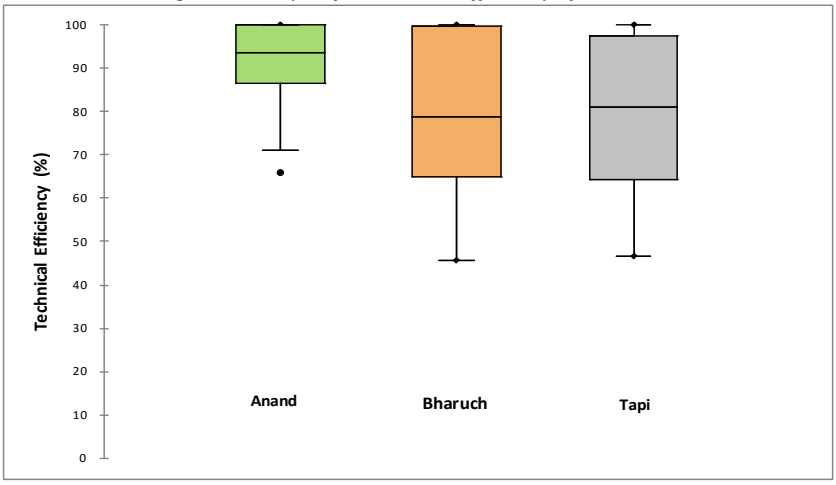
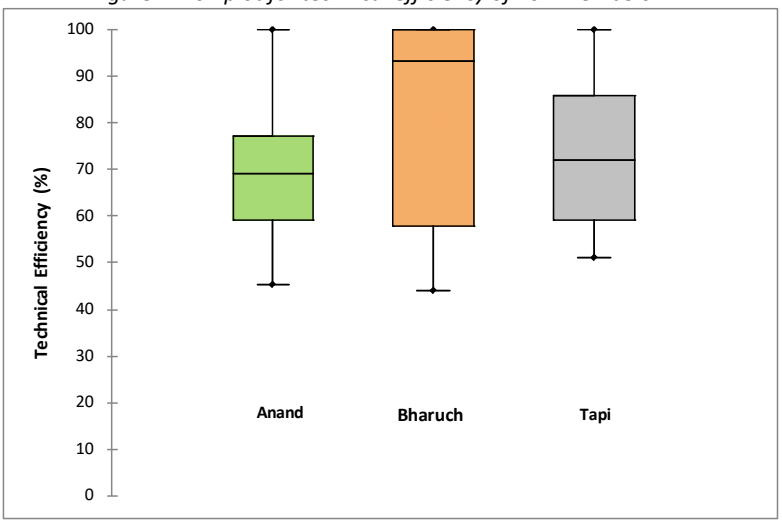
member farms across different level of dairy development for the selected districts for the pooled sample. A farmer with the least efficiency score (45.80%) among members was from Bharuch district and the district also had the highest variation in the efficiency score as indicated by the vertical length of box and whisker.

Figure 1. Box-plot for technical efficiency of members



It also revealed that across all districts, there was larger variation among the smaller efficiency values as indicated by the greater length of whisker on the lower side. Overall, farmers in Anand (91%) were the most efficient followed by Bharuch (80%) and Tapi (79.22%). Similarly, in Figure 2, the distribution of technical efficiencies of non-member farmers was depicted. The least efficiency score (44.10%) and highest variation were found in Bharuch, as in the case of members. Unlike members, in the case of non-members, the variation in the technical efficiency score was larger on the upper limit for Anand and Tapi with the exception of Bharuch as indicated by the length of the whisker. Altogether, farmers in Bharuch (80%) were more efficient, followed by Tapi (74.1%) and Anand (71.8%) in the case of non-members of dairy cooperative societies.

Figure 2. Box-plot for technical efficiency of non-members



4. Technical efficiency across herd size categories

Table 5 shows the technical efficiency of small, medium and large herd size farms of both member and non-member categories. The result revealed that in both the cases, farmers with small herd size were more efficient than medium and large herd size categories implying that a farmer can better manage the farm if the herd size is

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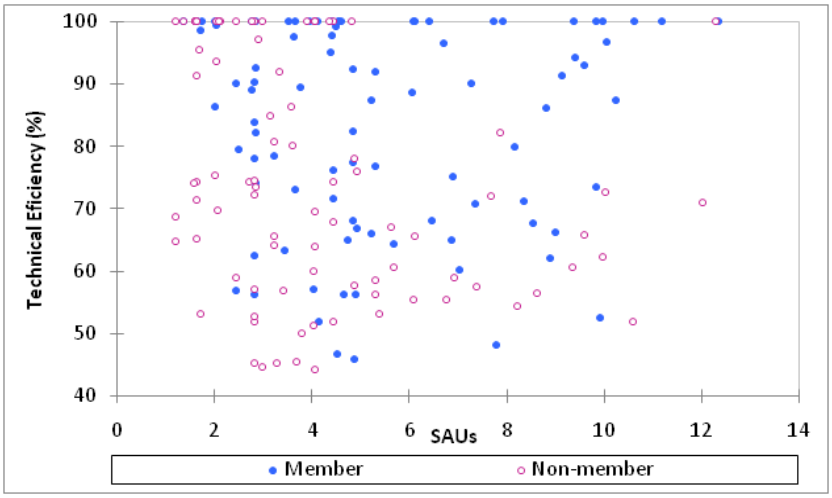
smaller. In the case of member farmers, the small herd size farmer's efficiency score was 87.21% while the same for non-member was 81.59%. Farmers with medium herd size were found least efficient (81.05%) among members, while in the case of non-members it was farmers with large herd size (67.19%).

Figure 3. Scatter plot for technical efficiency (%) vis-à-vis SAUs (n=180)



The research findings were similar to the results obtained by [2]. The wide difference in the efficiency score of farmers with small and medium herd size was due to higher inefficiency embedded with the medium category of farmers who mostly rear buffaloes. Large farmers were least efficient (67.19%) in the case of non-members as out of 12 non-member farmers with large herd size, nine were from the least developed district, Tapi.

Table 5. Technical efficiency across herd size categories

Technical efficiency (%)	Parameter	Member			Non-member		
		Small	Medium	Large	Small	Medium	Large
Upto 49.99	Minimum	-	45.80	48.00	44.50	44.10	-
	Mean	-	46.25	48.00	44.80	44.87	-
	Maximum	-	46.70	48.00	45.10	45.40	-
50.00 - 59.99	Minimum	56.20	51.80	52.40	51.80	50.00	51.90
	Mean	56.50	55.30	52.40	54.68	54.95	55.03
	Maximum	56.80	57.00	52.40	58.90	58.80	57.50
60.00 - 69.99	Minimum	62.30	63.30	62.00	64.70	60.00	60.50
	Mean	62.30	65.75	63.975	67.00	64.87	62.83
	Maximum	62.30	68.10	67.60	69.60	69.40	65.80
70.00 - 79.99	Minimum	74.10	71.60	70.70	71.40	74.20	71.00
	Mean	77.17	75.44	73.83	73.64	76.00	71.83
	Maximum	79.50	78.40	79.90	75.30	78.00	72.60
80.00 - 89.99	Minimum	82.20	82.40	86.00	-	80.00	82.20
	Mean	85.30	86.90	86.70	-	82.95	82.20
	Maximum	89.00	89.30	87.40	-	86.20	82.20
90.00 – 100	Minimum	90.10	91.80	90.00	91.30	91.90	100.00
	Mean	97.56	98.33	97.30	73.06	99.10	100.00
	Maximum	100.00	100.00	100.00	100.00	100.00	100.00
Overall mean		87.21	81.05	83.60	81.59	71.14	67.19

Figure 3 shows the distribution of farmers across herd size and technical efficiency score. The scatter plot showed that the number of non-member farmers with small and medium herd size was high and most of them fall under medium category (4-7 SAUs) to form a cluster over the lower efficiency range. Non-member farmers

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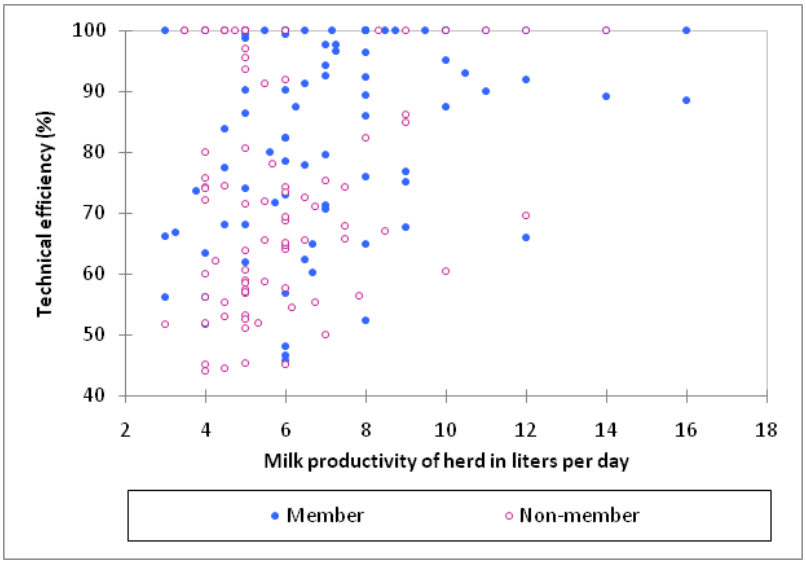
with large herd size were also found to be positioned over lower efficiency range. In the case of dairy cooperative members, only a few medium herd size farmers were falling above 85% of efficiency whereas a significant number of respondents were found below 80% of efficiency level.

Member and non-member farmers are positioned across technical efficiency vis-à-vis productivity of their herd as measured in liters per day (Figure 4). The scatter plot corroborates the fact it is not necessary that a farmer producing more output should be more efficient. The figure also indicated that a majority of the member farms have higher milk productivity in comparison to their counterparts.

Figure 4. Scatter plot for technical efficiency (%) vis-à-vis herd milk productivity



4. Conclusions

The dairy sector is indispensable to Indian agriculture and cooperatives have played a crucial role in the development of the dairy sector. Dairy cooperatives provide inputs, technical services, and information to the farmers which influence their ability to perform the dairying more efficiently. The study was set to measure and compare the technical efficiency of the dairy cooperative member and non-member farmers in the three districts of Gujarat having a different level of dairy development. The technical efficiency score was computed using the DEA approach. The results revealed that a majority of the farmers, especially non-member farmers in the study area use the available resources and technology sub-optimally and produce less than the potential output in comparison to members.

The mean technical efficiency score for members in all the three district-wise comparisons was found to be more efficient than their counterparts and maximum divergence was found in the highly developed district i.e Anand. In the relative comparison of the three districts, dairy cooperative member farmers from Anand were most efficient, followed by Bharuch and Tapi while in the case of non-members, farmers from Bharuch were most efficient followed by Tapi and Anand. Clearly, 21% of inefficiency in milk production exists in the study area, which shows the scope for improvement with the given technology and same level of resources. Further, it was found that farmers with small herd size were highly efficient in the case of both members and non-members. The study concludes that membership in dairy cooperatives, herd size and dairy development status of a region greatly influences the technical efficiency of farmers.

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